

# *The International Journal of Meteorology*

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**Volume 42, number 402**

**March/April 2017**

**Severe Thunderstorms over England, 27 August 2016**

**TORRO Tornado Division Report: September - December 2016**

# Extreme Weather

Forty Years of the Tornado and Storm Research Organisation (TORRO)

*Robert K. Doe*

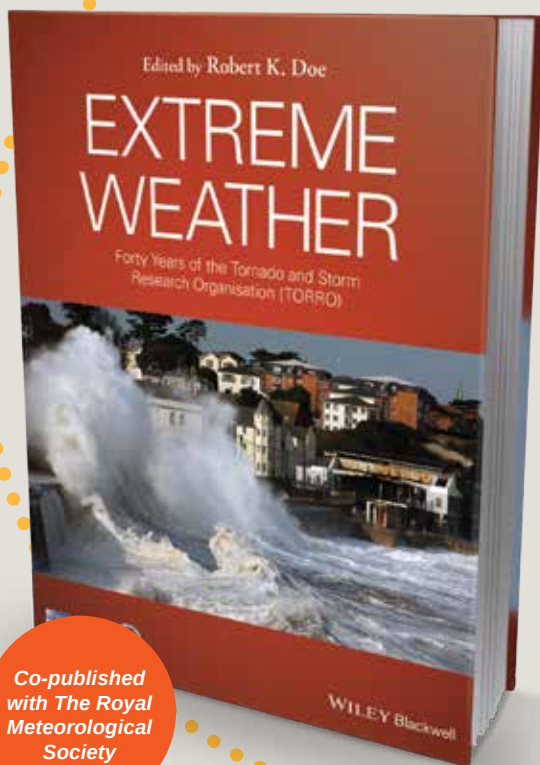
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# ***The International Journal of Meteorology***

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# ***The International Journal of Meteorology***

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*Cover image:* © **CHRIS BELL**. April showers over the Norfolk landscape, 25 April 2017.



## WEATHER ANNIVERSARIES: MARCH/APRIL

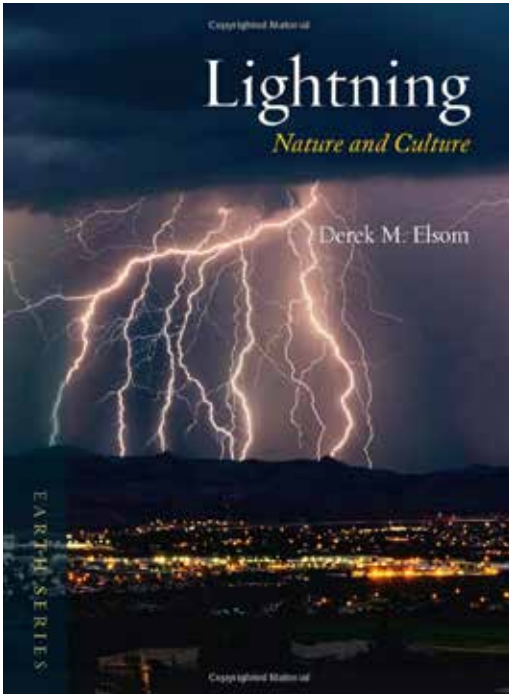
**25 years ago**, westerly winds prevailed for much of March 1992 but a brief polar outbreak brought drifting snow showers to the north in mid-month; 20 cm was reported at Wick on the 14th and the maximum temperature at Lerwick that day was only  $-3.3^{\circ}\text{C}$ . A longer lasting northerly outbreak in the last week of the month gave further snowfalls over northern hills. It was a wet month except in the south, and notably dull in many places. Large daily rainfalls of 50-80 mm occurred at the western hill stations several times between the 6th and 21st. Westerly gales on the 12th gave gusts of 75 knots in Shetland and 69 knots at Leeds; and Culdrose (Cornwall) recorded 78 knots in northerly gales on the 26th. At the end of March a cold cyclonic northeasterly type gave a prolonged rainfall in northeast England and southeast Scotland, where many places received over 100 mm in three days from 30 March to 1 April (228.9 mm at Sourhope, Roxburghshire). The rest of April had a mixture of cyclonic and (brief) anticyclonic spells. It was a wet month in most parts and again quite dull. A T4 tornado occurred in North Yorkshire on the 25th in a showery southwesterly airflow.

**50 years ago**, in 1967 the strong westerly pattern of the second half of February continued until nearly the end of March, which lived up well to its reputation for windiness, especially in the north. At Lerwick hourly mean speeds of force 6 (22 knots) or higher occurred on all but one of the first 25 days, and gusts exceeded 70 knots at times. These strong westerlies rising over the Western Highlands produced a very wet month here, where several stations received over 700 mm; daily falls reached 75-100 mm on the 24th (106.2 mm at Kinloch Hourn, Inverness-shire). Much of the rest of Britain, however, was drier than usual. During a northerly spell at the end of the month 10 cm of snow accumulated in the north of Scotland. April was predominantly anticyclonic but the frequency of polar winds made it a rather cool month. It began with a widespread sharp frost, as low as  $-6^{\circ}\text{C}$  in the south and  $-9^{\circ}\text{C}$  in the north; but a warm spell in mid-month gave temperatures up to  $22^{\circ}\text{C}$ . Despite the high pressure some places in the east and north had more rain than normal, but most had a dry month (only 25% in parts of the southwest).

**75 years ago**, the first part of March 1942 saw a continuation of the wintry weather of January and February. Very cold easterly winds led to heavy snowfalls from the 4-6th as a front stagnated in the west; level depths of 25 cm were reported from northern England and Scotland accompanied by deep drifts. The 6th was the coldest March day on record in central and eastern England: maximum temperatures were below freezing generally and as low as  $-2.8^{\circ}\text{C}$  in some places. There were also severe night frosts, including  $-9.4^{\circ}\text{C}$  at Milford, Surrey, and  $-15^{\circ}\text{C}$  or lower in the Scottish Highlands on the 8th. The second half of the month was generally warmer. In April easterly winds were again more frequent than usual, but were often brilliantly clear, resulting in the second sunniest April in the record (from 1929). Abnormally dry air developed in a stiff northeasterly breeze

on the 15th, when relative humidity fell to 15% at some southern stations (e.g. Kew and Boscombe Down: dry bulb +14°C, dew point -12°C); temperatures reached 23°C in the north at about this time. Despite unsettled weather in the first ten days, April's rainfall was less than half the normal in parts of the east.

**100 years ago**, the sequence of cold months that had begun in December 1916 continued through March and April 1917. March was unsettled with rain or snow at times. Severe frost was general in the second week and included readings of -12°C or lower in many places; in the Grampians, where snow was reported 50 cm deep, the temperature fell to -19.5°C at Braemar on the 8th. After variable winds in March, April had a predominance of north or northwesterlies, making it the coldest April of the 20th century. Polar lows in the early days of the month produced remarkably heavy spring snowfalls in many districts, e.g. 25 cm at Meltham, Yorks, 28 cm at Shrewton, Wilts, 30 cm at Broadford, Co. Clare (this was the second great snowstorm in western Ireland that year). Very low night temperatures at this time included -9°C at Broadford, -11.5°C at Meltham, -12°C at Norwich, -14.5°C at Eskdalemuir; and there were reports of day maxima of 0°C or lower. Wintry weather persisted until after mid-month (Dumfries had 30 cm of snow lying on the 11th), but a strong anticyclone in the last 10 days was accompanied by warmer weather everywhere, and the start of a drought.



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# SEVERE THUNDERSTORMS OVER ENGLAND, 27 AUGUST 2016

BY WILLIAM S. PIKE<sup>1</sup>  
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## ABSTRACT

An increasingly organised area of thunderstorms crossed England on 27 August 2016. These storms were associated with small vortices and waves which formed and moved along a boundary line front between two airmasses (1) Tropical continental (Tc) and (2) Tropical maritime (Tm). These storms were often severe, with reports of almost-continuous thunder and lightning, moving from central southern England to Lincolnshire and Yorkshire during the afternoon and evening. On (mostly) the eastern flank of the storm zone, large hail 20-30mm across occurred in several separate areas around Oxford, Northampton, Peterborough/Deeping and Boston; some oblate hailstones were up to 40mm in length.

## SURFACE SYNOPTIC INTRODUCTION

As with the 28 July 2014 case study (see Pike, 2016, mesoscale charts, p. 232) the 27 August 2016 event involved a 'Double structure' frontal system separating three distinct airmasses, namely (1) Polar maritime (Pm) (2) Tropical maritime (Tm) and (3) Tropical continental (Tc).

Very hot Tc air, typically with surface dew point temperatures of at least 18°C by day, covered adjacent parts of continental Europe throughout the fourth week of August 2016, with occasional thunder towards its western boundary, marked progress northwards over southeast England on the 24<sup>th</sup>. This incursion of Tc air also produced an extreme UK temperature record for that particular date in August (see Webb and Meaden, 2000, p.304, also TORRO, 2017) of 33.9°C at Gravesend-Swanscombe in Kent, before retreating southward into the continent for a time, again with its progress being accompanied by thundery activity during the early hours of the 26th in Sussex and Kent, before much fresher Pm air moved south-eastwards temporarily.

After a brilliantly sunny (Pm) day on the 26th, a transient ridge of high pressure drifted north-eastwards, producing radiation fog and single-figure minimum temperatures in the Welsh Valleys beneath clear skies (see Figure 1, the mesoscale surface chart for 0300 UTC on the 27th) simultaneously with temperatures of 21°C in the Paris area of France (where there was still evidence of a residual "Heat Low"), giving astonishing thermal contrast with Wales!

Meanwhile, an occluded depression was moving closer to southwestern Ireland, and the pressure gradient began to increase, driving the two warm fronts northwards. By 0600 UTC (Figure 2) the leading warm front was lying from Plymouth (Devon) to Cromer (Norfolk) and was giving moderate outbreaks of showery rain (heard drumming on the roof at Woodlands St Mary in West Berkshire at 0450 UTC) particularly in the

Figure 1. Mesoscale synoptic chart for 0300 UTC on 27 August 2016, drawn by W. S. Pike based on information supplied by the Met Office via BADC and Paul Brown.

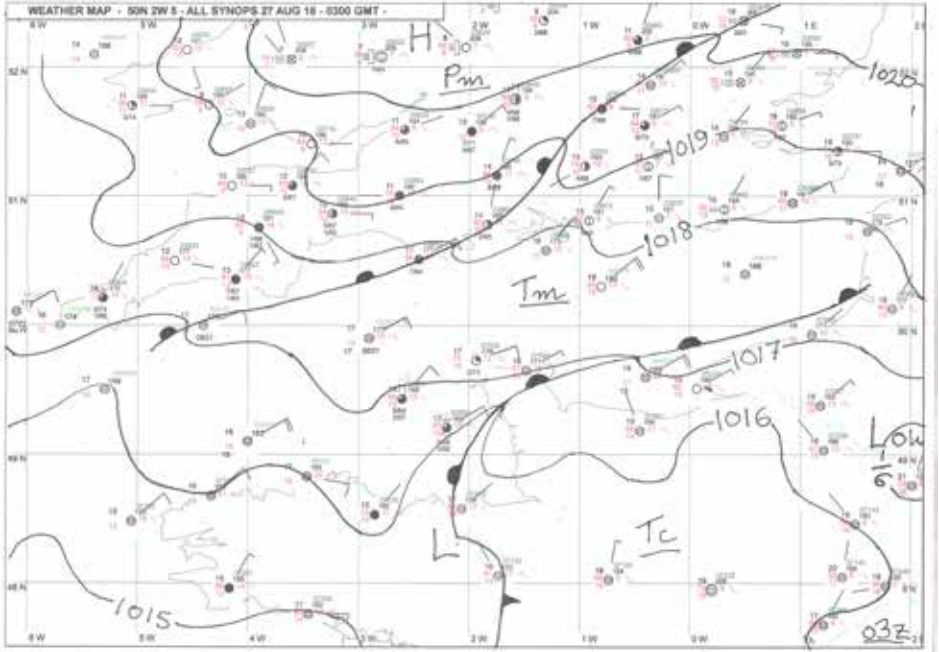
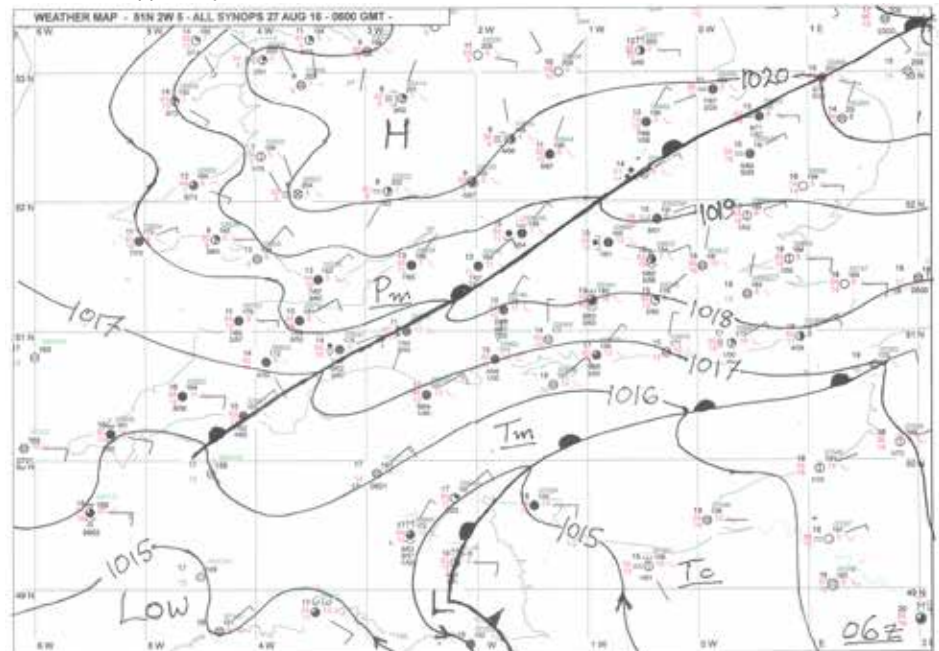


Figure 2. Mesoscale chart for 0600 UTC on 27 August 2016, drawn by W. S. Pike based on information supplied by the Met Office via BADC and Paul Brown.



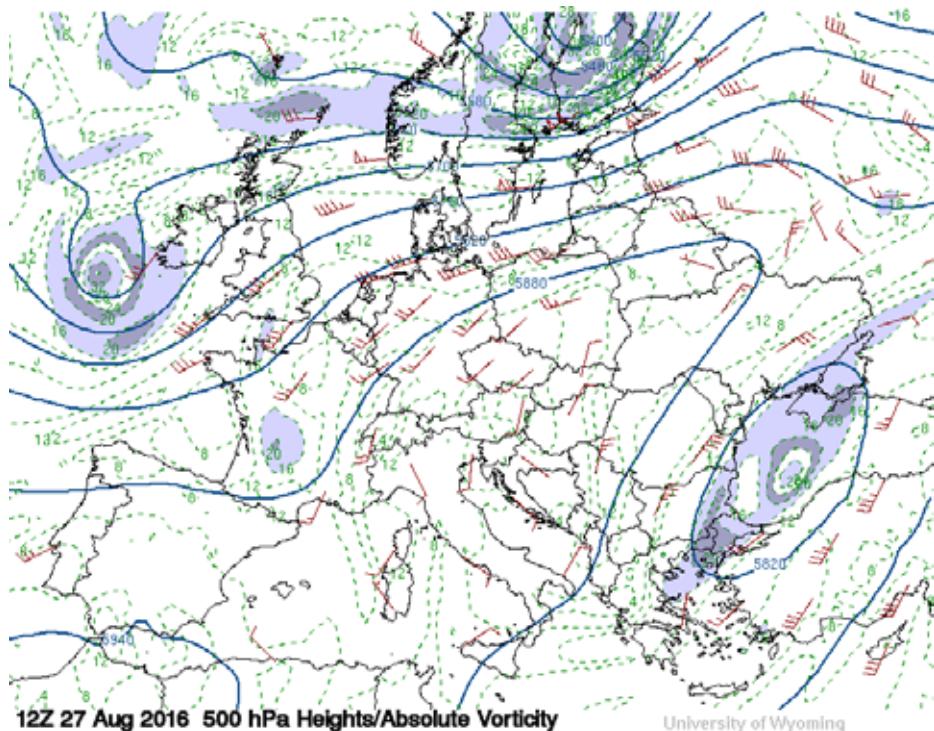
Bedford area, where a minor frontal wave was forming. The second warm front was moving steadily northwards over the eastern English Channel, but was poorly-defined, and represented more of a 'boundary line' between Tm and Tc air, when sea surface temperatures in the Channel were around 17°C, inhibiting convective cloud formation.

At 0600 UTC, surface temperatures continued to show a striking contrast, with 7-9°C across central Wales and the western Midlands in Pm air; at Velindre (Powys), COL observer John Goodger recorded an air minimum of 4.9°C with 1.1°C on the grass, indicating that conditions were favourable for a ground frost in the most prone locations. In comparison, at 0600 UTC temperatures were 17-19°C in Sussex and Kent with dew points up to 17°C in the Tm air.

### THE UPPER AIR

Meanwhile, a major upper trough was approaching Ireland and the west of Britain, as evident on the 500 hPa (Figure 3) and 300 hPa charts. The windflow at 500 hPa corresponds broadly to the 'thunderstorm steering' wind level, while 300 hPa is approximately associated with windflow at cumulonimbus anvil level. Figure 3 also indicates a small 'short wave' upper trough and associated swathe of vorticity crossing central southern England at 1200 UTC. Forced ascent (contributing to the release of instability) would be expected close to this feature, as well as, increasingly, ahead of the main upper vortex.

Figure 3. 500 hPa chart 1200 UTC, 27 August 2016. Courtesy of University of Wyoming, USA.



The 1000-500 hPa thickness chart for 1200 UTC also showed a very strong thermal gradient 'in depth' across Britain, between 544 dam at Lerwick (Shetland) and 568 dam at Herstmonceux. The 'inner' warm front moved into southeast England around 0900 UTC (Figure 4) and by 1200 UTC (Figure 5) was lying from Dorset to Norfolk. By 1100 UTC, screen temperatures had reached 25-26°C in parts of southeast England and East Anglia and 32°C in northern France. By 1400 UTC, temperatures had reached 35°C in Paris and afternoon temperatures of 28°C were recorded in Kent despite patchy mid-level cloud.

Figure 4. Mesoscale chart 0900 UTC on 27 August 2016, drawn by W. S. Pike based on information supplied by the Met Office via BADC and Paul Brown.

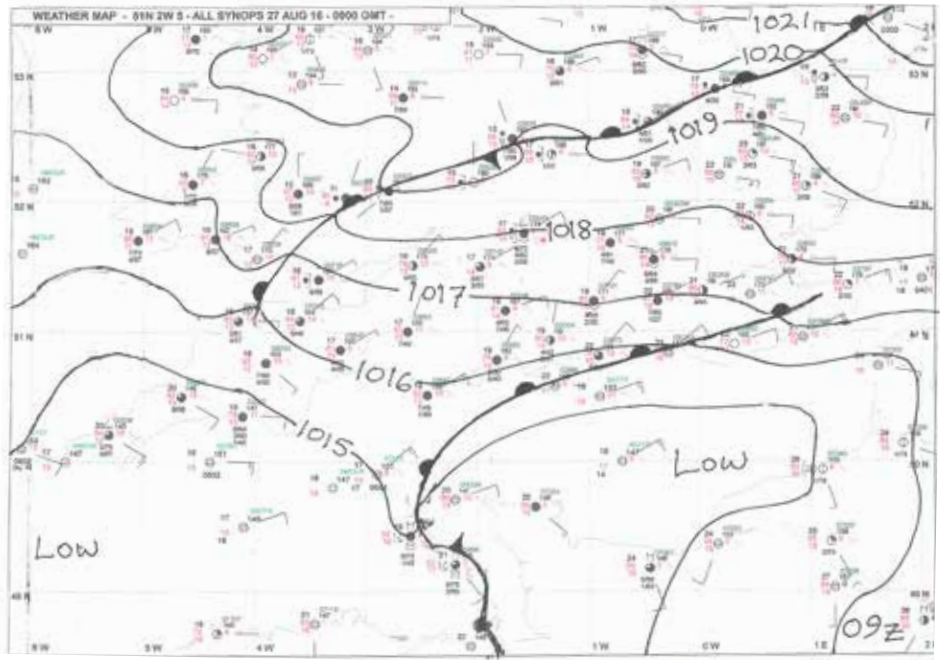
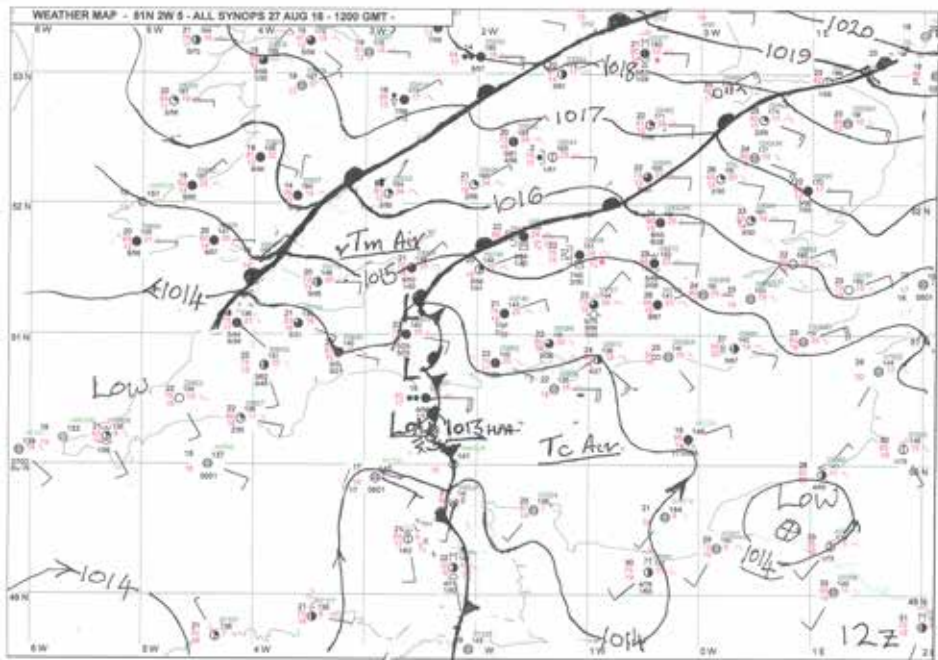


Figure 5. Mesoscale chart 1200 UTC on 27 August 2016, drawn by W. S. Pike based on information supplied by the Met Office via BADC and Paul Brown.

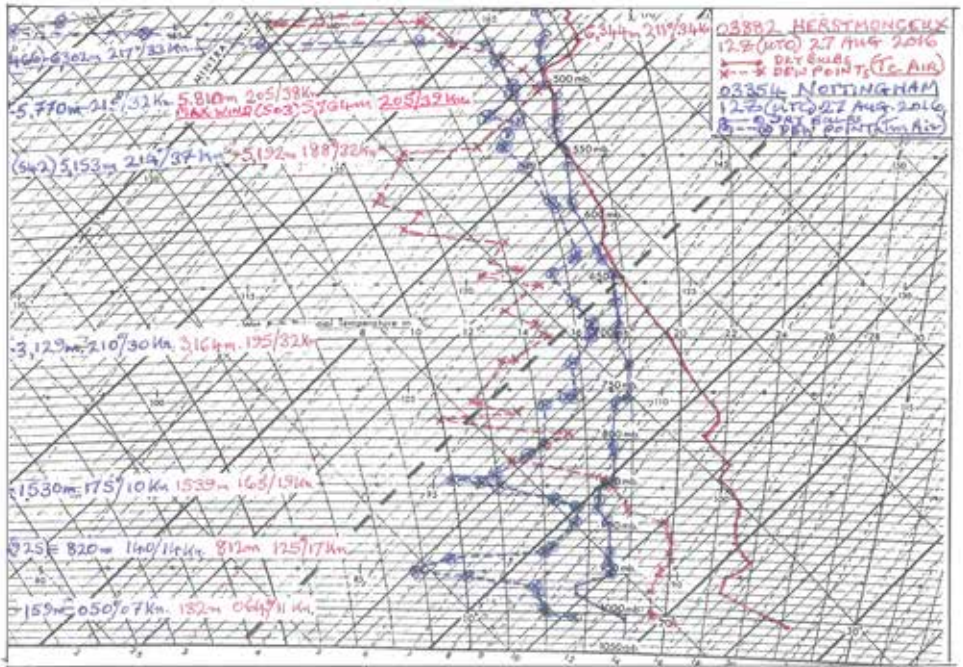


Comparison between the Nottingham and Herstmonceux 1200 UTC upper air ascents (Figure 6) indicated that this inner frontal zone separated Tm air, moist through a considerable depth (at Nottingham), from Tc air, mostly drier and more unstable, albeit with shallow moist layers near the surface and around 500 hPa (Herstmonceux). The shallow moist layer near the surface (not evident in the Paris/Trappes ascent) was probably attributable to passage of the airstream across the English Channel at its seasonal warmest. Other conspicuous features of the Herstmonceux ascent included:

- (1) The warm nose from 950 to 800 hPa, a classic feature of the ‘Spanish Plume’ scenario as strongly heated air originating over the Spanish plateau (or around the Atlas Mountains) is carried northwards as an elevated plume (Elevated Mixed Layer) at approximately the altitude it originated (Carlson and Ludlam 1968, Bennett et al 2006, Clark and Smart 2016).
- (2) The very steep environmental lapse rate from just above 800 hPa to 500 hPa, with >5°C difference between this and the SALR<sup>1</sup> parcel curve, indicating strong latent instability. This height range included the 0°C level; Ludlam and Macklin (1960) noted the correlation between severe hail events and an especially steep lapse rate from cloud base to the freezing level. It may be noted that the Bordeaux ascent at 0000 UTC displayed similar buoyant instability at mid-levels above a conspicuous warm nose (with close to 2,000 J/kg of CAPE) compared to the more stable Brest ascent in the Tm air (Figure 7). Bordeaux was around 500 miles/805 km ‘upwind’ of Oxfordshire (just over 12 hours for air moving at 40 knots).

1 Saturated adiabatic lapse rate

Figure 6. Herstmonceux/Nottingham 1200 UTC ascents, for 27 August 2016, drawn by W. S. Pike, based on information from University of Wyoming, USA.



(3) Potential instability associated with a fall in  $WBPT^2$  between 900 and 800 hPa and 500 and 400 hPa.

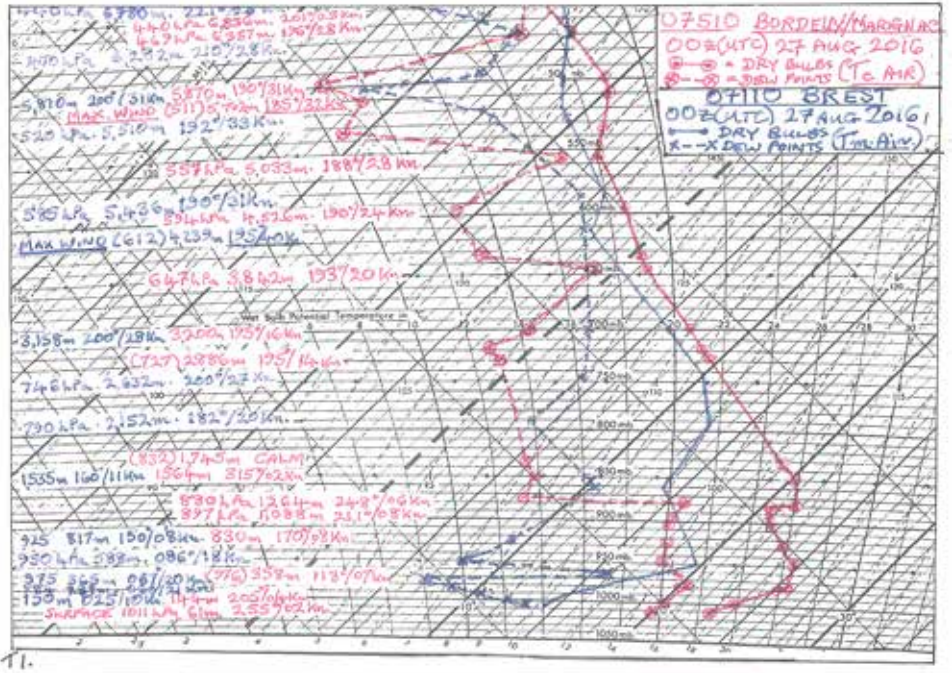
Similar radiosonde features were described by Betts (2003) in an analysis of the severe Ireland thunderstorm event of 25-26 July 1985 and Bennett et al (2006) in relation to the severe thunderstorm episode across the Midlands and northern England on 19 June 2005 (Webb 2010). Both those events resulted in the development of a mesoscale convective system, albeit of even greater magnitude than on 27 August 2016; these 1985 and 2005 storm events also featured hail of up to 30 to 40mm diameter.

The Herstmonceux ascent at 1200 UTC (Figure 6) also featured a very high value of CAPE (Convectively Available Potential Energy<sup>3</sup>) for the UK. Deep layer wind shear was also present, favourable for storm organisation. There was strong directional shear from the surface to 850 hPa and further significant speed and directional shear further above (See Figure 6 which also includes data for Nottingham).

2 Wet bulb potential temperature

3 Represented by the difference between the parcel curve and the environmental lapse rate

Figure 7. Brest/Bordeaux 0000 UTC Ascents, 27 August 2016, drawn by W. S. Pike, based on information from University of Wyoming, USA.



### DEVELOPMENT OF THUNDERSTORMS

A single sferic was recorded near Bedford shortly after 0700 UTC, near a ripple developing on the leading warm front (see Section 1 and Figure 2). No further electrical activity was picked up until more than an hour later when a sferic appeared just west of Guernsey between 0815 and 0830 UTC. This proliferated into quite an active cluster of lightning discharges by 0845 UTC (both Jersey and Guernsey airports reported thunder at 0900 UTC) and grew further by 0930 UTC, aligned SSW-NNE; between 1015 and 1030 UTC this storm cluster made landfall around Portland Bill.

Meanwhile an isolated discharge occurred in a shower west of Reading at 1020 UTC (a sferic was confirmed by thunder heard in Reading) and shortly afterwards, a small cluster of sferics popped up in the Newbury area, adjacent to Walbury Hill (where a curtain of rain was observed), between 1030 and 1045 UTC. The latter developed into a significant storm by 1100 UTC (Figure 8) with thunder heard east of Woodlands St Mary (West Berkshire) from 1037 to 1045 UTC and to the west of Benson and Crowmarsh (Oxfordshire) from 1055 UTC.

Figure 8. Met Office ATD sferics in the hour to 1100 UTC on 27 August 2016 (from Netweather).  
© Crown Copyright 2016 Met Office.



Indeed, this Oxfordshire storm was most intense from 1130 to 1215 UTC (Figure 9, 10) accompanied by hail 20-30mm diameter (Figure 11) at various locations (Figure 12). TORRO's first listed report of large hail came from Steventon, downwind<sup>4</sup> of the Ridgeway, and featured some oblate pieces of ice up to 40mm in longest dimensions which fell around 1130 UTC (Chequers Garage, Steventon, 2016). Apart from an isolated broken greenhouse window, hail damage further north appears to have been confined to extensive stripping of leaves off trees, as observed by one of the authors during a cycle ride through west Oxford, Kennington, Bayworth and South Hinksey on the following day.

Both a 'gap' in the ground reports of hail (Figure 12) and a brief but noticeable drop in radar reflectivity (from values  $>55$ dBz, and up to around 60 dBz<sup>5</sup>, around Abingdon and Oxford) indicate that large hail probably ceased, temporarily, for a few kilometres north of Oxford city before fresh intensification of the storm occurred on approaching Bicester (where hail at least 30mm diameter was observed); indeed the renewed swath of radar returns over 55 dBz (locally 60 dBz) extended several kilometres north-northeast of Bicester (Figure 13). This cell did decline from 1230 UTC; however, developments were becoming increasingly complex with new, electrified cells over west Oxfordshire (Brize Norton reported thunder at 1129 UTC) and Milton Keynes/Bedford (Figures 10, 14).

<sup>4</sup> Referring to mid-level storm-steering wind.

<sup>5</sup> On the standard Marshall Palmer index, a reflectivity of  $\geq 55$  dBz correspond to precipitation rates of over 100mm per hour while a return of  $\geq 60$  dBz indicates a precipitation intensity of over 200mm per hour (see also Figure 13 and caption).

Figure 9. UK Composite rainfall radar 1200 UTC on 27 August 2016, © Crown Copyright 2016 Met Office.

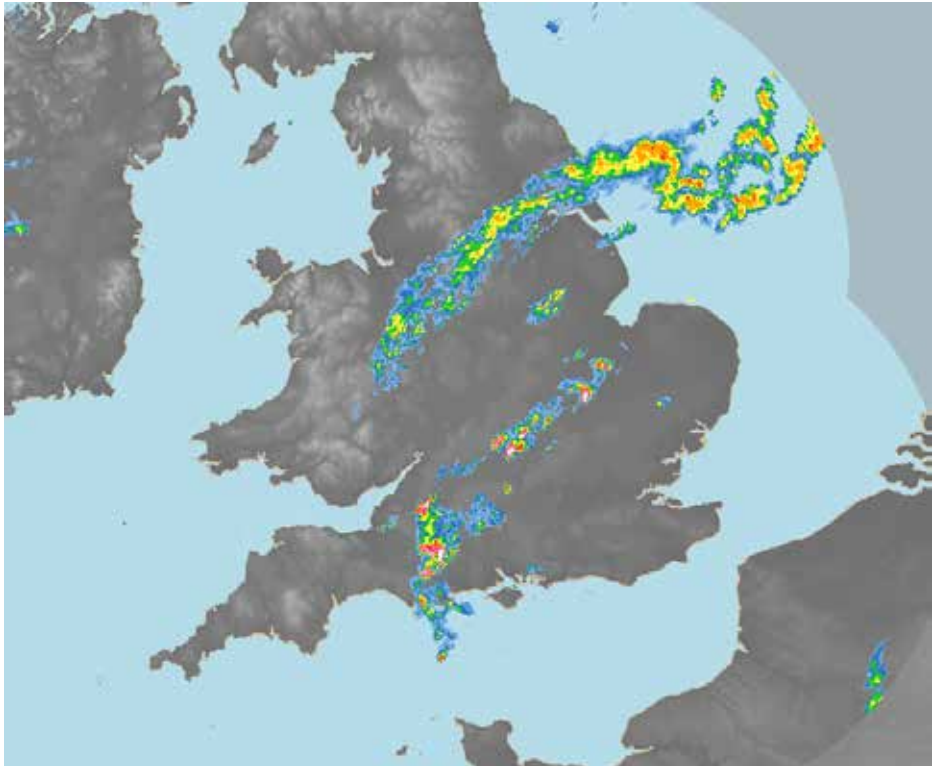


Figure 10. Met Office ATD sferics in the hour to 1200 UTC on 27 August 2016 (from Netweather). © Crown Copyright 2016 Met Office.

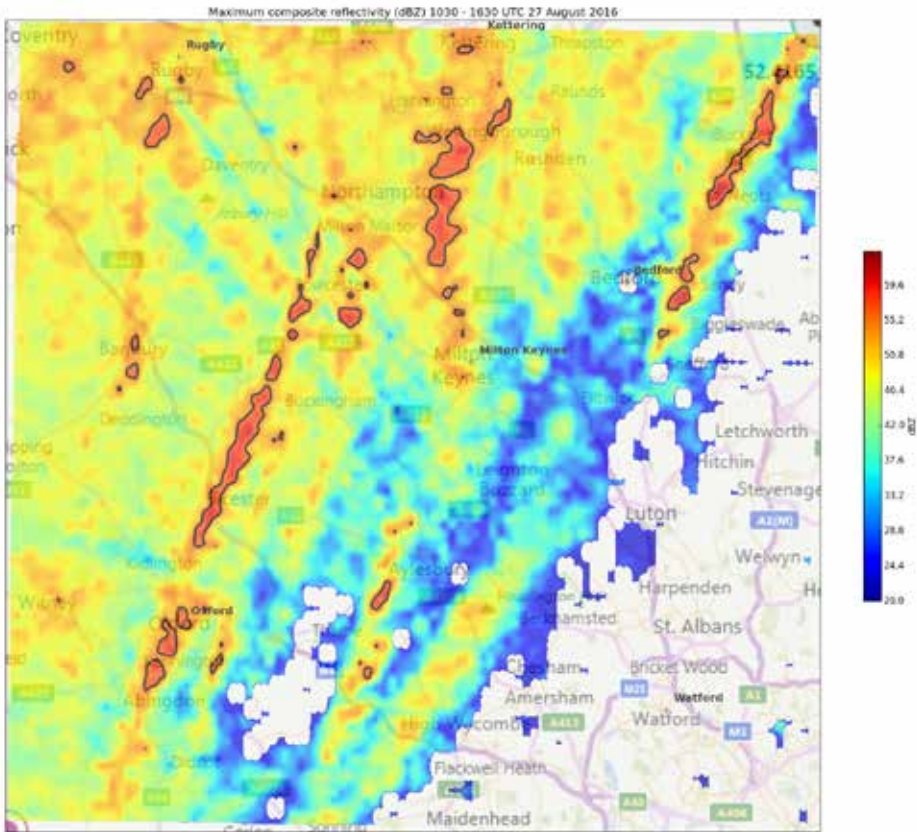




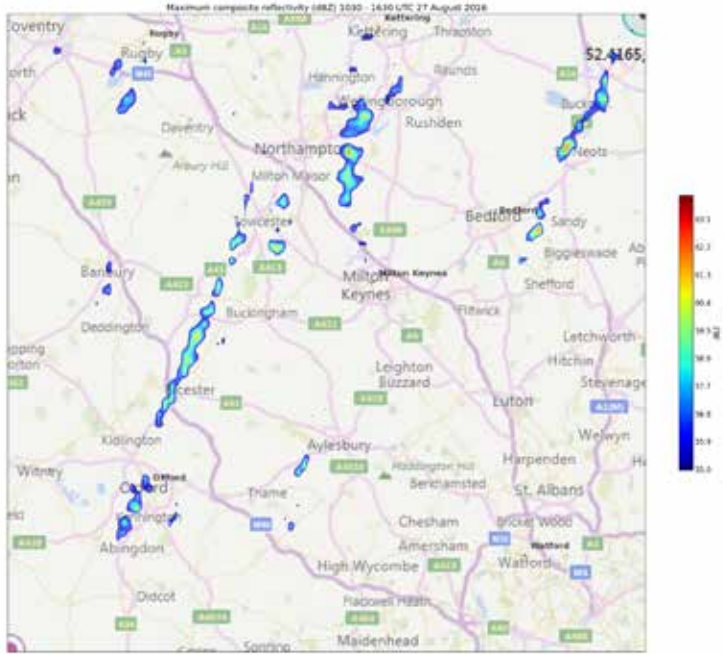
Figure 13 (a), (b) and (c). Maximum radar reflectivity (dBZ) 27 August 2016, representing lowest elevation angle (i.e. 1 degree above horizontal) scan data from the nearest radar. © Crown Copyright 2016 Met Office. The height (above radar level, not necessarily local ground) varies with range, i.e. about 0.35 km height at 20 km range, 0.70 km at 40 km range. Data is mapped onto a 1 km horizontal radar grid. Data on 13b and 13c is restricted to returns over 55 dBZ to enable greater resolution.

Various studies, e.g. Atlas and Ludlam (1961) and Hardaker and Auer (1994), have indicated that hail is likely to be present with a reflectivity of >55 dBZ and that values >60 dBZ are often associated with hail over 3/4 inch (≥20mm) diameter. There are several 'variables' which affect this relationship and are more accurately resolved by dual polarisation radars (Lewis and Silkstone 2017); however, Figure 13 shows quite good correlation between the 60 dBZ level of reflectivity and severe hail reports in Figure 12. Plots of precipitation intensities at 5 minute intervals (1km radar, courtesy NetWeather via Paul Brown) showed that the first intensities over 100mm/hr (55 dBZ occurred at 1125 UTC south-west of Oxford).

(a)



(b)



(c)

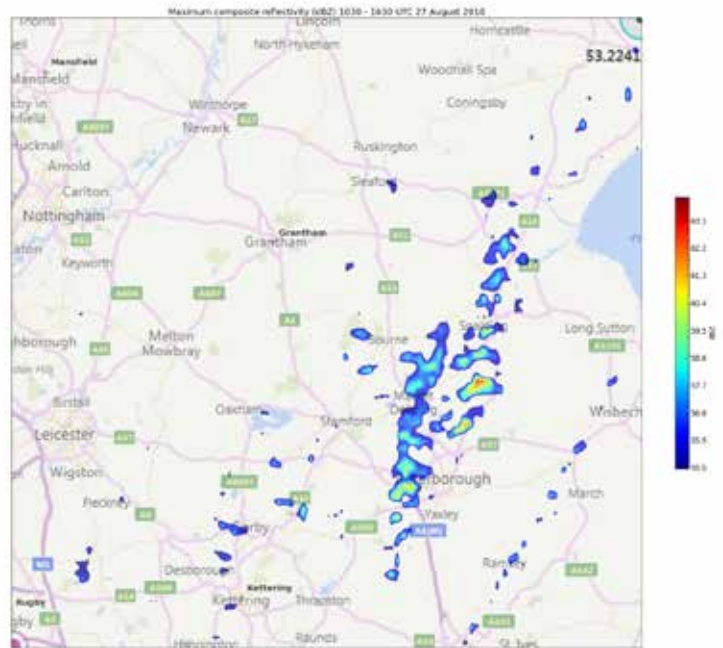
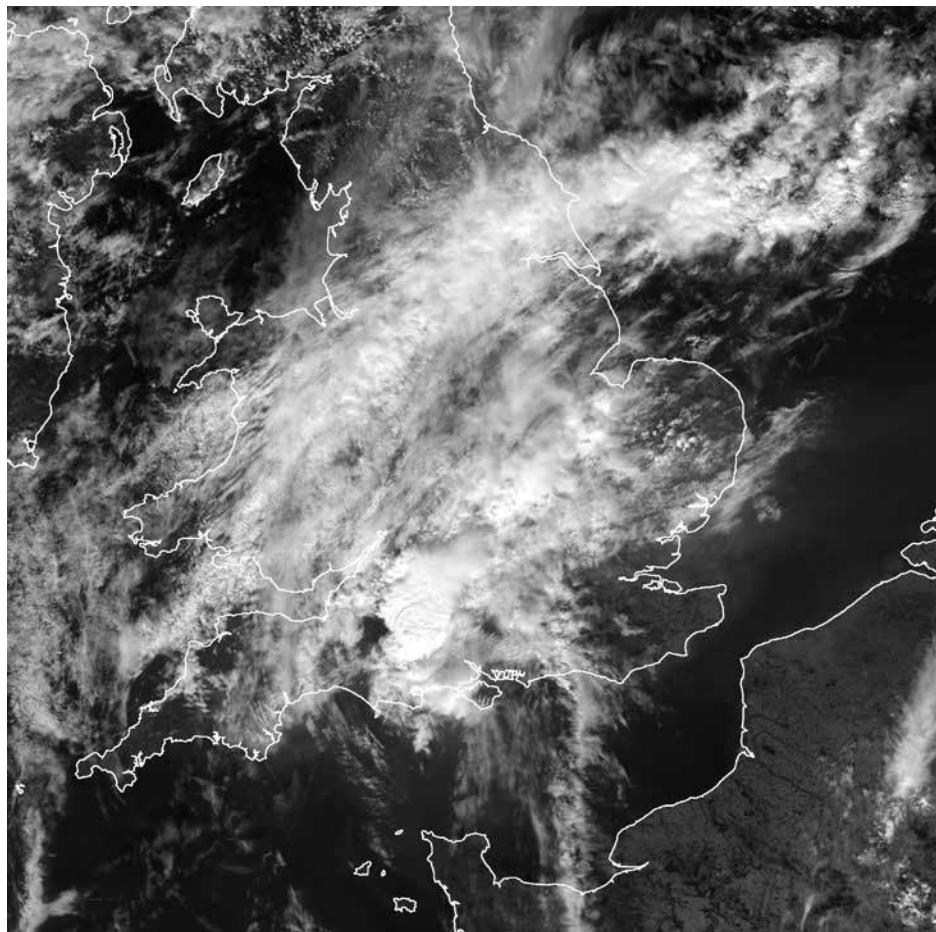


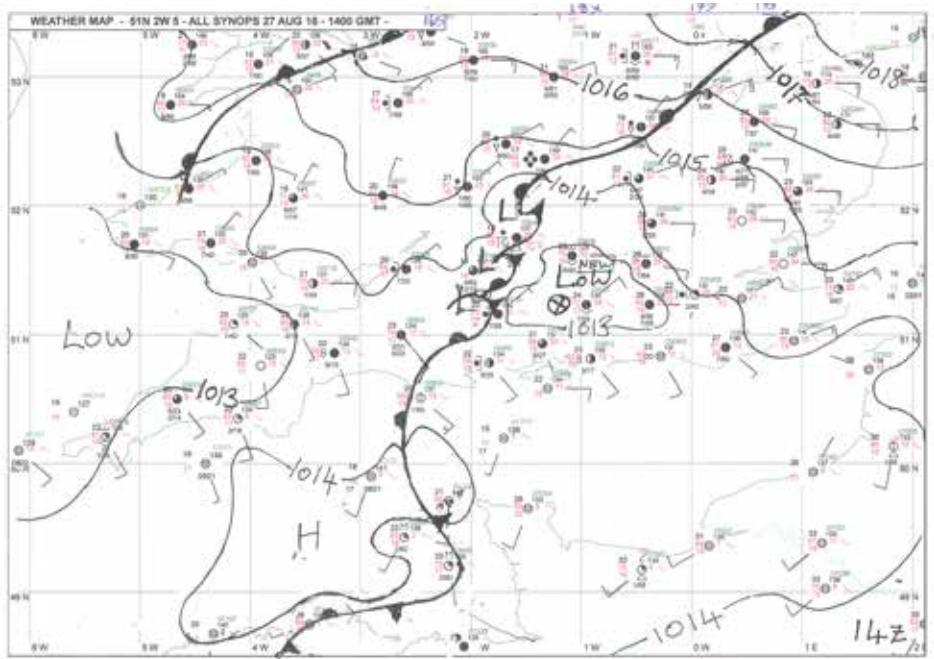
Figure 14. Visible satellite image 1224 UTC on 27 August 2016, courtesy of University of Dundee © 2016.



This late morning activity was closely aligned with the 'inner' warm front (Figure 5) which lay from Portland to Cromer at 1100 UTC. This front was slowing to a halt and beginning to develop ripples, and at the same time will have been engaging the short wave upper trough referred to in section 2 above. Along this frontal zone, isolated sferics also occurred in the Fenland area in mid-morning, with thunder heard at Ely at 1030 UTC.

Meanwhile, from 1045 to 1200 UTC, a dense area of sferics covered much of Dorset, this confirmed by ground observations of frequent thunder at Dorchester and Blandford. This storm cluster extended into Wiltshire and Somerset from 1200 to 1300 UTC. At Larkhill on Salisbury Plain, automated instrumental records indicated that 6mm of rain fell in 3 minutes from 1308-1311 UTC with visibility reduced temporarily to 200m (data from P. T. Brain, Larkhill Met Office). An observer nearby at Amesbury confirmed thunder was heard shortly afterwards, at 1330 UTC. This oscillating line of thunderstorms

Figure 15. Mesoscale chart for 1400 UTC on 27 August 2016, drawn by W. S. Pike based on information supplied by the Met Office via BADC and Paul Brown.



reached Woodlands St Mary (West Berkshire) by 1308 UTC, lasting there until 1418 UTC and accompanied by hailstones 5 to 6mm diameter for 2 minutes from 1355 UTC. As this 'main' storm cluster moved north-north-east, further development occurred on its western flank, over the Cotswolds.

Further north, at least three funnel clouds were observed from Kidlington (Oxford) airport, shortly after a close lightning strike one-and-a-half miles to the west at 1415 UTC. "Three or four funnel clouds" appeared below the main Cb base which was reported at 3,300 ft (1km) in the 1420 UTC METAR observation. The duty ATCO<sup>6</sup> noted that the largest of these funnel clouds extended "about one-third of the distance from the main Cb cloud base to the ground, and I could see the rotation as it passed nearly overhead". A "wall of water" (very heavy rain but no hail) struck their west-facing windows in the Control Tower towards 1430 UTC (Torrance, C. – *Pers. Comm.* to W. Pike). Figure 15 indicates these incidents occurred close to a triple point on one of the small frontal waves.

#### DURATION OF THUNDERSTORMS AND PRECIPITATION

Observers in several locations reported 2½ to 4 hours of continuous thunderstorm activity during the course of the afternoon, such as at: Swindon (1230-1520 UTC), Marlborough (1345-1634 UTC), Charlbury (1200-1445 UTC), Cosby, Leicester (1225-1555 UTC) and Coningsby, Lincolnshire (1446-1650 and 1900 UTC). At both Brize Norton (Oxon) and Wellesbourne (Warws) 21mm of rain fell between 1400 and 1500 UTC with the former

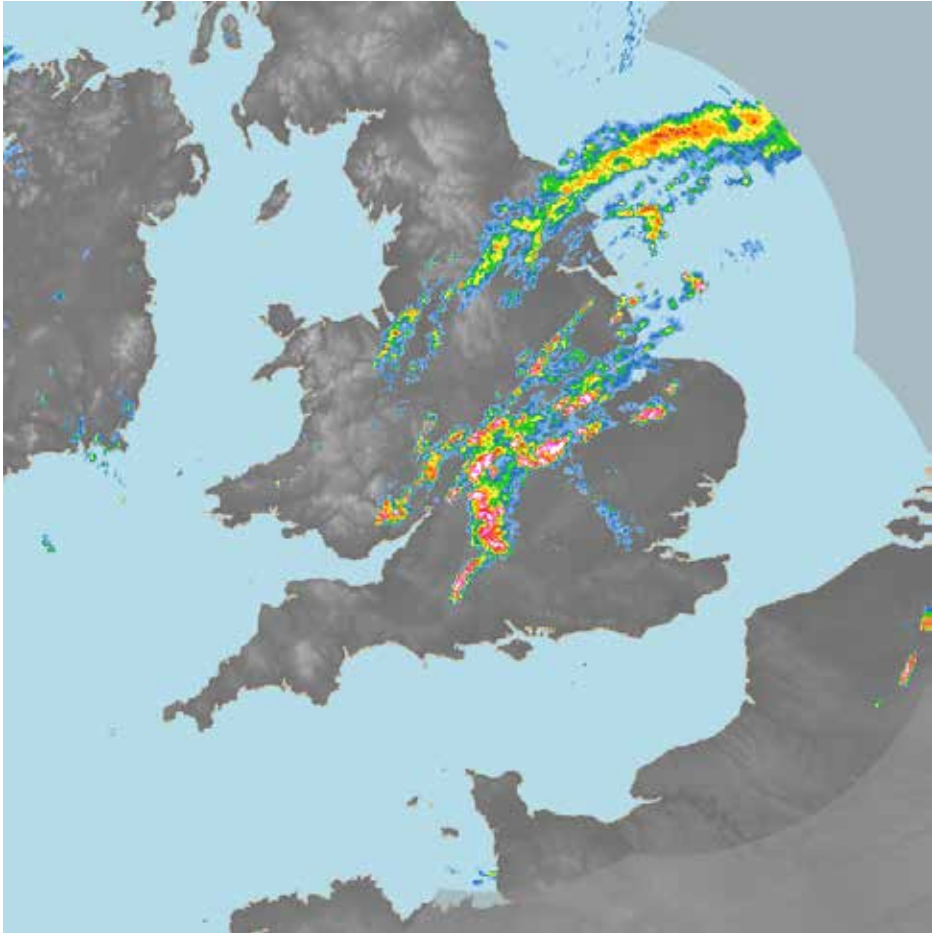
Figure 16. Hailstones at Northampton-Cogenhoe on 27 August 2016, 1400 UTC, courtesy James Whitaker © 2016.



registering a gust (from 260°) of 38 kn at 1359 UTC soon after the heavy rain had begun. In the Rugby area, Long Lawford recorded 34mm of rain and Church Lawford 32mm (in three hours). Other rainfalls of 30mm or more (from the Met Office/EA and COL networks) are noted in Table 1.

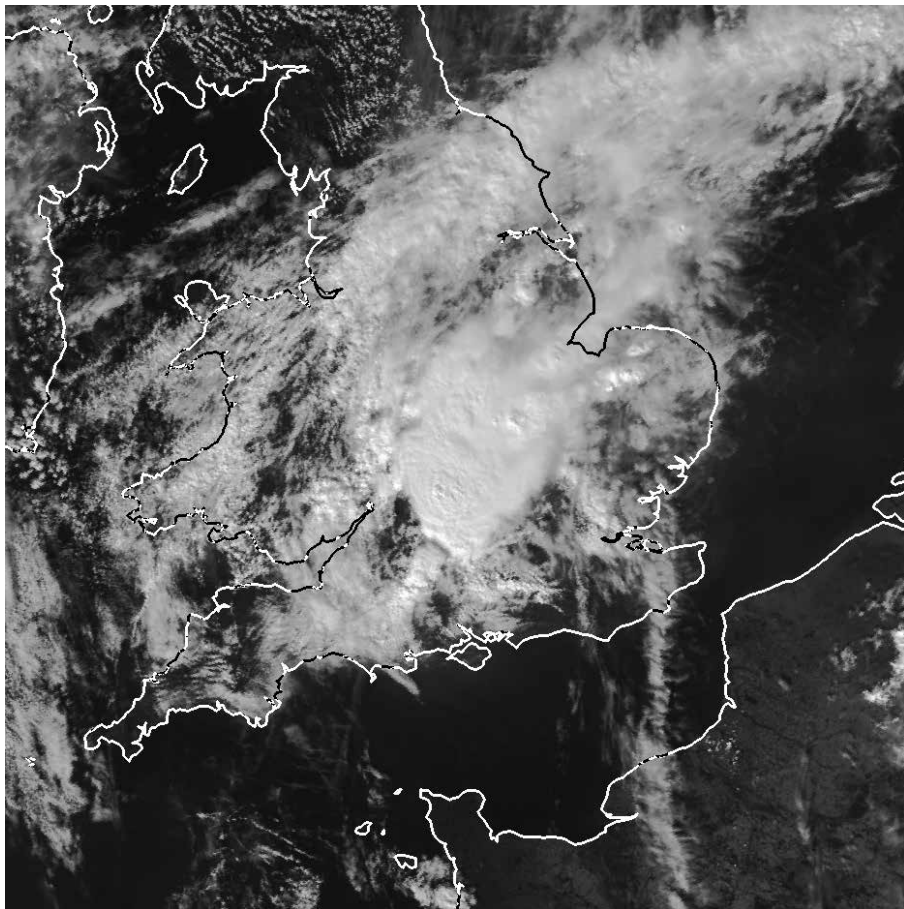
The second 'outbreaks' of large hail affected the Towcester and Northampton areas from 1400 to 1430 UTC (Figure 12, Figure 16). These intense cells are evident in the 1400Z radar (Figure 17) while the plots of maximum reflectivity (courtesy of Matt Clark, Met Office) show a significant area of returns over 55 dBz just east of Northampton. At Cogenhoe (Figure 16), the hail dented car bodywork and damaged some greenhouses and outbuildings (Whitaker, J. – *Pers. Comm.*); radar reflectivity exceeded 60 dBz in the vicinity (Figure 13), an intensity evident near Northampton on the 1400 UTC 1km radar. Later, around 1530 UTC, similar size hail fell in the Peterborough and Market Deeping areas (Figure 12). Perhaps the most severe storm impact of all occurred in the Boston area of Lincolnshire. A private observer measured 60.7mm of rain with 23.6mm falling in 31 minutes from 1627 to 1658h; marble sized hail also fell in the town, while in the village of Landrick 25mm hailstones were observed. Vehicles were reported to have been dented by hail in both the Peterborough and Boston areas. Peak radar reflectivities across the Fenland and south Lincolnshire are shown in Figure 13, and display a good correlation between the strongest returns and 'ground reports' of large hail. It may be noted that most grain crops will have already been harvested, so reducing the impact of the hailstorms on arable farming areas, in contrast to hailstorms which affected eastern England on 20 July 2016<sup>7</sup>.

Figure 17. UK Composite Radar 1400 UTC on 27 August 2016, © Crown Copyright 2016 Met Office.



Between 1345 UTC and 1400 UTC, an initially separate storm cluster developed around the Breckland on the Suffolk/Norfolk border. Radar reflectivity indicated two corresponding swaths of intense returns over 55 dBz (100mm/hour) as this storm moved quite rapidly northwards between 1400 and 1500 UTC, and this is supported by ground reports of hail about 16mm diameter from Houghton Hall and Burnham Market. In fact, peak radar returns appreciably over 60 dBz (200mm/hr) were recorded locally over north Norfolk and as the storm cluster moved out over the North Sea, suggesting that some larger hail ( $\geq 20$ mm diameter) may have been present here.

Figure 18a. Visible satellite image for 1413 UTC on 27 August 2016, courtesy of University of Dundee © 2016.

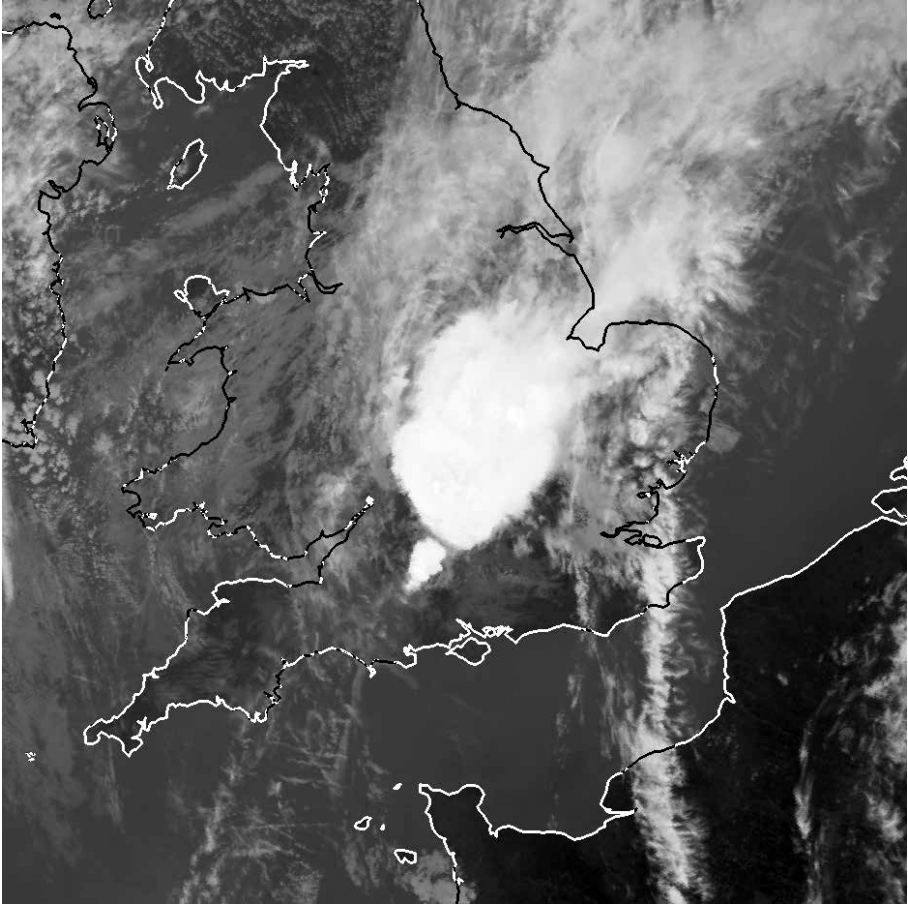


#### A MESOSCALE CONVECTIVE SYSTEM: CLOUD FORMATIONS AND IMPACTS

By mid-afternoon (see Figures 17, 18) the expanding storm cluster had begun to assume the satellite 'signature' of a Mesoscale Convective System (MCS) as described by Gray and Marshall (1998), with an extensive anvil shield. Overhead thunder and lightning had been reported across an extensive area in the hour from 1400 to 1500 UTC (Figure 19) although, with the 'wriggling' frontal system (Figures 20-21) the main trigger, the sferics and radar footprints (Figure 22) indicated a more elongated organisation of storms than with the classic MCS. However, by 1600 UTC (Figure 23) a contiguous area of precipitation covering an area at least 160km long and 100km wide had developed, characteristic of an MCS, and this reflected in the heaviest falls of rain occurring in Lincolnshire (Table 1).

The strong gust fronts flowing out from the storm zone were highlighted by numerous observations of impressive shelf clouds, while a conspicuous feature of skyscapes just

Figure 18b. Infra-red satellite image for 1413 UTC on 27 August 2016, courtesy of University of Dundee © 2016.



north of the frontal zone were the spectacular *Undulatus* clouds, specifically the species which is the newest addition to the International Cloud Atlas: *Undulatus Asperitas* (WMO 2017). These wave clouds (conspicuous in both the Northampton and Peterborough areas) reflected both the undercutting storm outflow and its lifting of stable Tm air in an environment of significant wind shear (see Figure 24; BBC 2016).

Observations and photographs of cloud bases through the main storm zone generally confirm that the thunderstorms were primarily the result of the release of marked instability at mid-levels, independent of surface insolation. As well as synoptic forcing, high ground (e.g. the Hampshire Downs) probably contributed to the release of this instability. Moreover, the outflow generated by these storms appears to have triggered some boundary layer convection on the right flank; this was probably the origin of the funnel clouds reported north of Oxford. It may be noted that a TORRO Tornado Watch

Table 1. Daily rainfall amounts exceeding 30mm across Central South England, the Midlands and Lincolnshire on 27 August 2016 (24 hours from 0900 UTC). EA = Environment Agency; COL = Climatological Observers Link; BADC = British Atmospheric Data Centre (Met Office Land Stations dataset).

Station	Lat/Long	Rain mm	Source
Guthram Gowt No2 (Lincs)	52° 48'N, 0° 16'W	44.6	Met Office/EA
Osournby (Lincs)	52° 56'N, 0° 24'W	42.2	Met Office/EA
Skegness (Lincs)	53° 9'N, 0° 21'E	40.7	Met Office/BADC
Spalding S Wks (Lincs)	52° 49'N, 0° 78'W	38.4	Met Office/EA
Frampton S Wks (Lincs)	52° 56'N, 0° 22'W	38.0	Met Office/EA
Oadby (Leics)	52° 35'N, 1° 5'W	37.0	COL
Braunston S Wks (Leics)	52° 39'N, 0° 45'W	34.6	Met Office/EA
East Kirkby S Wks (Lincs)	53° 80'N, 0° 06'W	34.2	Met Office/EA
Long Lawford (Warws)	52° 23'N, 1° 19'W	34.0	COL
Kings Newnham (Warws)	52° 23'N, 1° 19'W	34.0	Met Office/BADC
Tisbury (Wilts)	51° 36'N, 2° 36'W	33.4	Met Office/BADC
Church Lawford (Warws)	52° 22'N, 1° 20'W	31.8	Met Office/BADC
Marlborough (Wilts)	51° 25'N, 1° 44' W	30.2	COL

Figure 19. Met Office ATD sferics in the hour to 1500 UTC on 27 August 2016 (from Netweather), © Crown Copyright 2016 Met Office.



Figure 20. Mesoscale chart for 1500 UTC on 27 August 2016, drawn by W. S. Pike based on information supplied by the Met Office via BADC and Paul Brown.

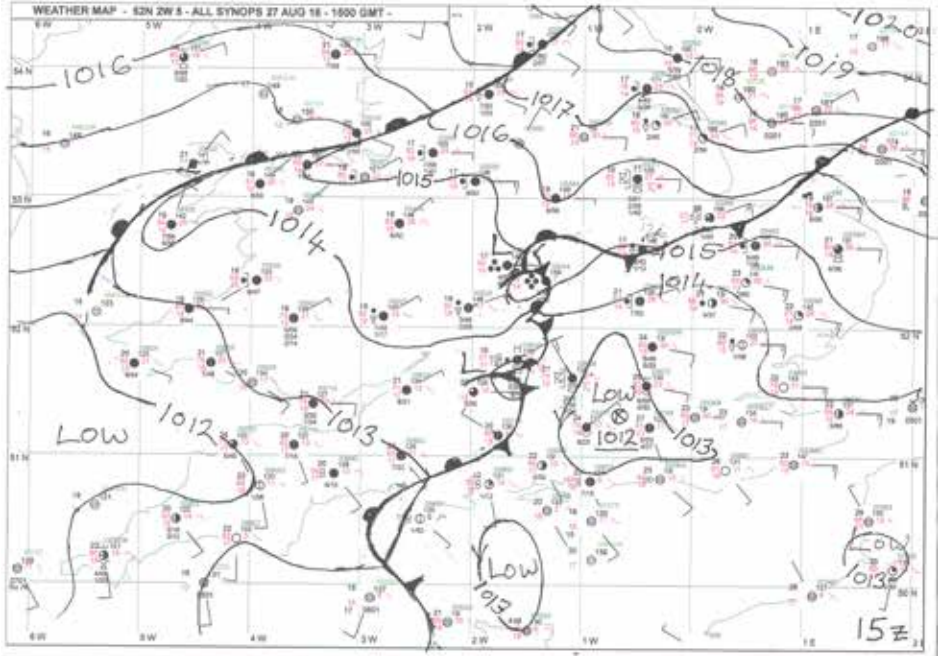


Figure 21. Mesoscale chart for 1800 UTC on 27 August 2016, drawn by W. S. Pike based on information supplied by the Met Office via BADC and Paul Brown.

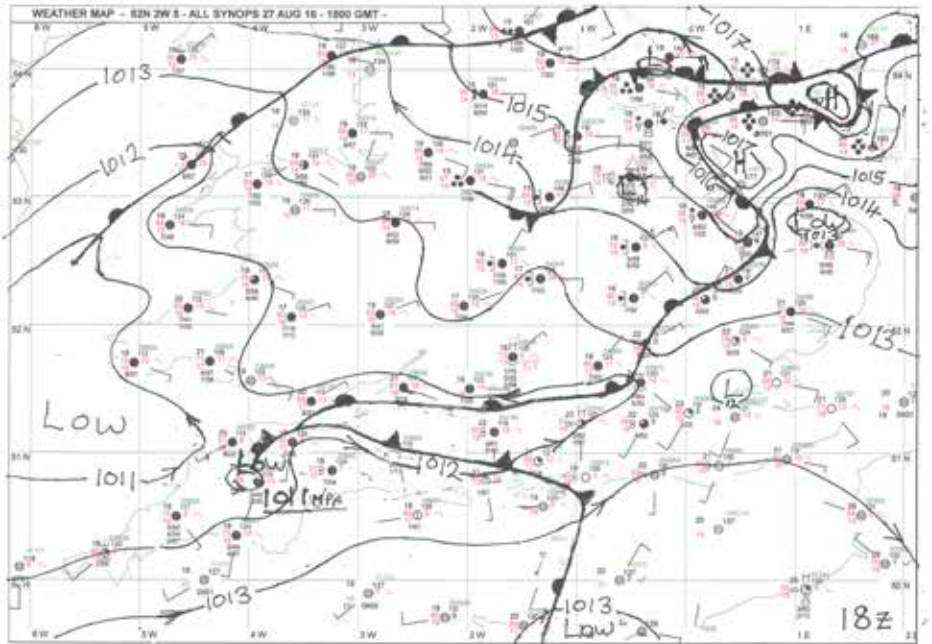


Figure 22. Composite UK radar 1500 UTC 27 August 2016, © Crown Copyright 2016 Met Office.

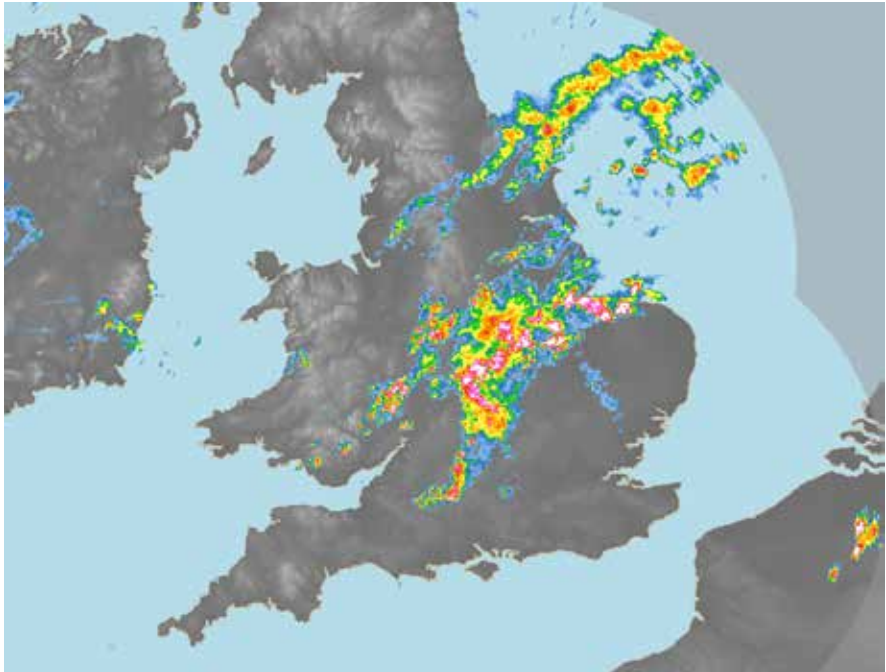


Figure 23. Composite UK radar 1600 UTC 27 August 2016, © Crown Copyright 2016 Met Office.

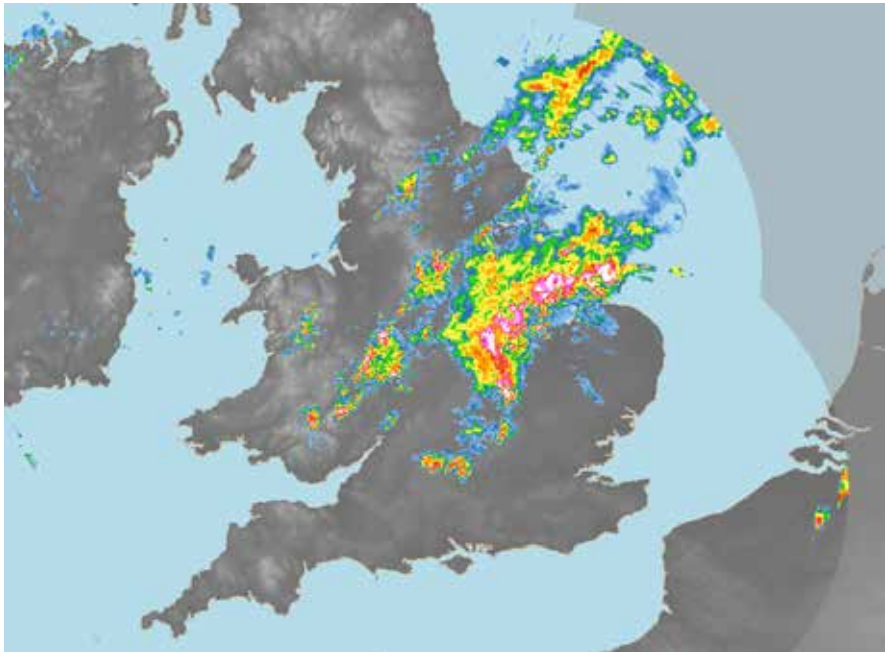


Figure 24. Undulatus clouds over Northampton, 27 August 2016, courtesy James Whitaker © 2016.



Table 2. Significant lightning incidents 27 August 2016 (south-north).

Time UTC (if known)	Location	County	Detail
1355~	Tisbury	Wilts.	A lightning strike at Tisbury, west of Salisbury, damaged rail signalling equipment, causing temporary closure of the Salisbury/Yeovil Junction route.
	Savernake	Wilts.	Damage was caused to the St Katharine's Primary School when a 500 year old oak tree was hit by lightning. A limb of the tree fell on the playground and electricity lines, completely destroying the school's play area and benches. Fire alarms, telephone and internet connections were also put out of action.
1400	Whelford, near Fairford	Glos.	Lightning struck and fired a barn
	Condicote	Glos.	Lightning struck and fired two large barns
1320	Shenley Lodge, Milton Keynes	Bucks	Lightning struck a two-storey block of flats
	Market Harborough	Leics	Lightning cut power to 2,000 homes
1515	Wigston, Leicester	Leics	Lightning struck and damaged the rear chimney and roof of the two-storey, disused, commercial building.

(also referring to the risk of hail up to 40mm diameter) had been issued at 1020 UTC (Knightley, P. – *Pers. Comm.* to TORRO Forum).

Although the most intense electrical activity missed the densely populated areas around London and (largely) the West Midlands, several incidents of damaging lightning strikes occurred and these are listed in Table 2.

The ‘outer’ warm front and ensuing trough sprung to life very late in the evening, with thundery rain overnight from Anglesey to Durham. This outbreak was closely associated with falling surface pressure and the proximity of the main upper low/vortex. High daily rainfall totals included 77.1mm at Llangoed, 65.0mm at Llansadwrn and 61.4mm at Beaumaris (all Anglesey). In contrast to the falls across southern and central England, much of the rain over north Wales fell after 2100 UTC.

#### ACKNOWLEDGEMENTS

Sincere thanks to: Paul Brown, TORRO, for synoptic and sferics data; at the Met Office, Matt Clark for the radar images and output including Figure 13, Mark Beswick and Joan Self (Archives) for rainfall data; Neil Lonie (University of Dundee) for satellite imagery; David Smart (UCL) for the Boston rainfall station data; all synoptic, TORRO and COL observers, also eye witnesses who submitted reports to the TORRO website and TORRO Facebook page.

#### REFERENCES

- Atlas, D and Ludlam, F.H. (1961) Multi wavelength reflectivity of hailstorms. *Q. J. Met Soc*, 87: 523–534.
- BBC (2016):  
<https://www.bbc.co.uk/weatherwatchers/article/37221584/Cloud-busting-Asperitas-cloud/> (accessed 7 February 2017)
- Bennett, L. J., Browning, K. A., Blyth, A. M., Parker, D. J. and Clark, P. A. (2006). A review of precipitating convection in the United Kingdom. *Q. J. Royal Met Soc* 132, 1001-1020.
- Betts, N. L. (2003) Analysis of an anomalously severe thunderstorm system over Northern Ireland. *Atmos. Res.*, 67–68, 23–34
- Carlson, T. N. and Ludlam, F. H. (1968). Conditions for the occurrence of severe local storms. *Tellus XX* (1968), 2.
- Chequers Garage Ltd, Steventon (2016):  
<https://twitter.com/chequersgarage/status/769498259337408512> (accessed 15 February 2017).
- Clark, M. and Smart, D. (2016). Supercell and Non-supercell Tornadoes in the United Kingdom and Ireland. In *Extreme Weather: Forty Years of the Tornado and Storm Research Organisation (TORRO)*, Ed Doe, R. John Wiley and Sons Ltd, London, Chichester, UK.
- Gray, M. E. B. and Marshall, C. (1998) Mesoscale Convective Systems over the UK, 1981-1997. *Weather* 11, 388-396.
- Hardaker, P. J., Auer, A. H. (1994) The separation of rain and hail using simple polarization radar and IR cloud top temperature. *Meteorol. Appl.*, 1, 201–204.
- Lewis, M. W., and Silkstone, N. (2017) Improvements in nowcasting capability: analysis of three structurally distinct severe thunderstorms across northern England on 1 July 2015. *Weather*, 72, 91–98.
- Ludlam, F. H., Macklin, W. C., (1959) Some aspects of a severe storm over south-east England, 5 September 1958. *NubilaVerona*, 1, 38–50.
- Pike, W. S. (2016) A travelling cold pool causes thundery re-invigoration of a dormant frontal system during the early hours of 28 July 2014. *Weather*, 71, 231-235.

TORRO (2017), British Weather Extremes: Daily Maximum Temperatures, available at: <http://www.torro.org.uk/hightempsyear.php> (accessed 29 April 2017).

Webb, J. D. C. (2010) Multiple large hail events over England and Wales as mesoscale convective system develops, 19 June 2005. *Weather* 65, 150–156.

Webb, J. D. C. and Meaden, G. T. (2000) Daily temperature extremes for Britain. *Weather* 55, 298–315.

Webb, J. D. C. and Pike, W. S. (2007) Thunderstorm squall associated with a mesoscale convective system, 22 July 2006. *Weather* 62, 270–275.

World Meteorological Organisation/WMO (2017). The International Cloud Atlas, Manual on the Observation of Clouds and Other Meteors (WMO-No. 407), available at:

<https://www.wmocloudatlas.org/home.html> (accessed 2 April 2017).

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## TORRO AUTUMN CONFERENCE 2017



The TORRO Autumn conference will be held on Saturday 14 October 2017 at the Oxford Brookes University in Oxford, United Kingdom.

The programme is available on the TORRO website [www.torro.org.uk](http://www.torro.org.uk) and the forum.

We are pleased to announce the conference will, once again, be free of charge to all.

To register for the conference please email through to **[membership@torro.org.uk](mailto:membership@torro.org.uk)**



## TORRO TORNADO DIVISION REPORT: September - December 2016

BY PAUL R. BROWN AND G. TERENCE MEADEN

September 2016 was a mainly southwesterly month apart from a brief hot spell in the middle, and the only confirmed whirlwinds were two funnel clouds. The last three months of the year were often anticyclonic. In October high pressure was to the northeast resulting in an excess of easterly winds, but cyclonic spells in the south resulted in one probable tornado, two waterspouts, and seven reports of funnel clouds. In November high pressure to the west produced more northerly winds than usual; but although whirlwinds occurred on only one day this month, that day produced a total of 12 recorded tornadoes. In December high pressure over the near-Continent often covered the British Isles and there were no confirmed whirlwinds.

tn?2016Sep13 *Ladybower Reservoir area, Derwent Moors, Derbyshire (c 53° 22' N 1° 43' W, SK 1986)*

The *Yorkshire Post* and others (13 September) published film (anonymous) taken from Sheffield, probably in the evening, showing a distant lowering from a thunderstorm cloud, but the nature of it is unclear. Tim Prosser of TORRO estimated that it would have been near the Derwent and Ladybower Reservoirs to the west of Sheffield, but when he visited the area on the 19th there was nothing to be seen.

At 1200 GMT a hot southeasterly airstream covered England (30°C in the east) associated with a depression of 1005 mb in the Bay of Biscay, from where a trough extended north through the Irish Sea. There were thunderstorms in many western and northern parts during the day.

A similarly doubtful report of a funnel cloud reaching the ground was received from Bewdley (Worcs).

q2016Sep15 *between Emmbrook and Twyford, Berkshire (c 51° 26' N 0° 51' W, SU 8072)*

Mr Chris Harries experienced a thunderstorm with substantial hail while travelling between Emmbrook and Twyford at 1640 GMT. He saw a fallen tree and heard of another one, and as there was no strong wind at the time he assumed that a tornado must have been responsible (but obviously not recordable as such).

At 1200 GMT a shallow ill-defined trough of low pressure covered the British Isles (main centre 1001 mb in the Bay of Biscay). Many areas had a dry day but isolated thunderstorms broke out in southern England in the afternoon followed by more widespread storms in the evening.

FC2016Sep19 *Guernsey, Channel Islands (c 49° 26' N 2° 36' W)*

Distant funnel clouds were reported in the 1220 and 1250 GMT METARs from Guernsey Airport. At 1200 GMT a ridge from the Azores covered western Britain while a weak northerly airflow affected the east. There was occasional rain or showers in central and southern England.

FC2016Sep20 *Lydd, Kent (50° 57' N 0° 54' E, TR 0430)*

Mr Liam Kenward forwarded a photograph (taken by a relative) showing a slender oblique funnel cloud nearly halfway to ground (time not stated). At 1200 GMT a ridge axis lay from southwest to northeast across England but there was an old weak front over the southeast. Most of England was dry but there were scattered showers near east and south coasts.

WS2016Oct01 *offshore Dover, Kent (c 51° 07' N 1° 20' E, TR 3340)*

Photographs were received showing a long funnel cloud offshore more than halfway to the surface, which no doubt would have reached the sea as a vortex (one correspondent confirmed this although the pictures do not show it). It was seen nearby from Dover (Mr Nigel Scutt) and at a distance from Dungeness (Mr Carl Roberts), from where it was timed at 0828 GMT.

At 1200 GMT an occluded low, 1003 mb, was drifting slowly east over Wales and England. Showers were widespread here, where some were accompanied by thunder, but more scattered over Ireland and Scotland.

tn2016Oct01 *Keyhaven, Hampshire (50° 43' N 1° 34' W, SZ 309915)*

The *Bournemouth Echo* of 4 October reported that a 'tornado' had passed through the boat yard of West Solent Boat Builders at Keyhaven (near Lymington) at 0845 GMT on Saturday. It lasted about 20 seconds, during which time the gate was blown open, stones were raised into the air, and about 20 dinghies overturned, some being badly damaged. The owner of the business, Mr Richard Attwell, said he did not see the funnel shape but judged that it was probably a tornado from the nature of the damage. Force T1. There were thundery showers in the area at the time.

FC/TN2016Oct01 *Eglinton Airport, Derry, County Derry (c 55° 03' N 7° 09' W, C 5322)*

A recent funnel cloud was reported in the 1120 GMT METAR from Eglinton Airport; and photographs taken by Mr Aaron Cairns show it over the Donegal hills to the west, where it descends below the highest tops perhaps reaching the lower summits (although it would be unlikely to have left any trace up there).

FC2016Oct01/I *Waddington, Lincolnshire (53° 10' N 0° 32' W, SK 9864)*

A funnel cloud was reported in the 1227 GMT SPECIAL from Waddington Airfield. Photographs were taken from Cherry Willingham (TF 0372) and Metheringham (TF 0661), untimed but probably of the same cloud; they show a vertical funnel approaching halfway to the ground.

tn?2016Oct01 *Pontardawe, Glamorgan (c 51° 43' N 3° 51' W, SN 7204)*

Nicky Llewellyn of TORRO drew our attention to film taken by Mr Andrew Stoneman from Pontardawe at 1330 GMT showing (at a distance) a broad ragged column from cloudbase to ground, or nearly so; Tony Gilbert of TORRO gave his opinion that this was condensation rising into an updraught rather than a proper funnel cloud or tornado, although conditions were ripe for such a development there.

FC2016Oct01/II *Pen-y-Fai, Bridgend, Glamorgan (51° 32' N 3° 36' W, SS 8982)*

Mr Tom Hughes photographed a rather large funnel cloud perhaps halfway to ground at 1352 GMT.

FC2016Oct09 *Cadishead, Lancashire (53° 25' N 2° 27' W, SJ 7092)*

The *Manchester Evening News* of 9 October published a photograph taken in the afternoon by Ms Hayley Garlick showing a contorted funnel cloud seen from Cadishead (outskirts of Manchester). At 1200 GMT a weak northeasterly airflow covered England and Wales within a ridge from a strong anticyclone over Scandinavia. In spite of the high pressure, showers developed in many central and eastern parts of England.

FC2016Oct10 *Ramsey Island, Pembrokeshire (c 51° 51' N 5° 21' W, SM 6923)*

A short cloud pendant was photographed offshore to the west of Ramsey Island (time and photographer unknown). At 1200 GMT the synoptic pattern was the same as on the previous day. There were showers again in central and eastern England and a few near the Welsh coast.

WS2016Oct12 *offshore Falmouth, Cornwall (c 50° 06' N 5° 04' W, SW 8130)*

The *West Briton* (12 October) published a photograph taken by Ms Ruth Littlejohns from Gyllyngvase Beach in the morning (probably about 0800 GMT) showing a funnel cloud nearly halfway to the sea, beneath which disturbance of the water is just discernible. Another witness said it was moving westward "about 15 or 20 miles out" (it looks much closer in the pictures).

At 1200 GMT an easterly airstream continued to cover the British Isles associated with a large anticyclone over Sweden. Showers affected central and eastern parts of England and Scotland, and a persistent narrow band ran westward close to south Cornwall all morning.

FC/WS2016Oct12 *offshore Whitstable, Kent (c 51° 22' N 1° 04' E, TR 1368)*

Several photographs were taken of this funnel cloud seen over the sea from Whitstable and Herne Bay, some of which were reproduced in *Kent Live* (13 October). They show it between a third and a half of the way to the surface, which means there was probably disturbance of the water beneath it (there is a hint of this in one or two of the pictures). The time is unknown.

FC2016Oct22 *Great Yarmouth, Norfolk (c 52° 36' N 1° 43' E, TG 5207)*

Photographs of this rather small funnel cloud, a third of the way to ground, were taken from Great Yarmouth towards northwest by Mr Michael Fish<sup>1</sup> at 1520 GMT; a similar view of it was taken from Caister-on-Sea (anon) at 1530 GMT. At 1200 GMT a northeasterly airstream covered England on the fringe of a large anticyclone over northwest Russia. There were showers in central and eastern areas of England and Scotland.

## TORNADOES OF 17 NOVEMBER 2016

At 1200 GMT on 17 November a large parent low, 976 mb, was situated north of the Faeroe Islands. During the day a frontal wave moved quickly east from southwest Ireland at 0600 GMT to central England by 1200 GMT and to the central North Sea by 1800 GMT, during which time it deepened from 998 mb to 980 mb. The pressure gradient round the wave was not abnormally strong; but as the cold front crossed Wales and the Midlands in the late morning reports began to come in of wind damage and isolated extreme gusts (e.g. 73 knots at Shawbury, much stronger than could be accounted for by the gradient wind). Three TORRO representatives (separately) investigated as many of

<sup>1</sup> Not his namesake of the 1987 hurricane.

these reports as they could - John Mason in west Wales, Matt Clark in east Wales/west midlands, Tim Prosser in the north Midlands.

There was a good deal of discussion within the organisation about how much of this damage could be attributed to tornadoes and whether some, at least, was caused by rectilinear winds (known informally as 'straight-line winds') such as microbursts. This brought to light two different approaches to tornado identification: one is that any wind damage suggestive of a tornado is classified as such unless there is clear evidence to the contrary; the alternative approach is *not* to call it a tornado unless all other possibilities have been ruled out.

tn2016Nov17/I *Clarach Bay, near Aberystwyth, Cardiganshire (52° 26' N 4° 04' W, SN 591838)*

National newspapers reported that up to 20 holiday caravans were overturned at Clarach Bay near Aberystwyth, where a gust of 82 knots was measured at the Lifeboat Station at 1034 GMT (trustworthiness of the instrument unknown). The owner of the site described the wind as a tornado on the strength of the damage (and perhaps because it has become fashionable for members of the public to attribute any sudden damaging wind to a tornado), but some TORRO staff expressed doubts (see below). Force perhaps T2.

Mr Jeff Thornton at Aberystwyth (personal communication) witnessed "at least two vortices pass by causing bins to blow over ... leaves were sucked high into the sky. One large branch was broken from a tree ...". He gave the time as 1020 GMT and mentioned thunder just before. The following day he traced damage from the Lifeboat Station to his location in Aberystwyth, and spoke to witnesses at Capel Dewi (SN 629823), who saw "vortices moving through and lifting tiles off houses with fairly new roofs ... two large trees down [but] other similar trees nearby untouched".

John Mason made an extensive survey of the area between Aberystwyth and Machynlleth in the days immediately after the event. Numerous trees suffered damage throughout this area and, near the coast, there were instances of buildings being damaged. Four clusters of more intense damage to trees stood out: these were centred on Clarach (SN 6083), Capel Dewi (SN 6382), Tre'r-ddol (SN 6592), and 2 km northeast of Tre'r-ddol (SN 6793); but only in the third cluster, beginning at Llancynfelyn (SN 642921), did the damage show something like a track, elsewhere it was more widely dispersed. Further investigations to the east on 25 November revealed four more clusters of severe damage (trees again): at Cwmyrhaiadr Farm (SN 7596), where there was a trail of intense damage up to 200 m wide (the most severe of all); south of Talbontrain (SN 7895); north of Cefncyfrifol Farm (SN 8096), where the distance to which branches were thrown might have required the agency of a vortex; and at Llanbrynmair (SH 8902). Beyond this point there appeared to be only isolated damage until the next major sequence was found some 30 km further east by Matt Clark (see below).

John Mason's assessment, however (as an experienced tornado investigator), was that the evidence in his area did not clearly indicate tornadoes except perhaps very locally, and that all or most of it could be explained by other forces. All the tree falls were in approximately the same direction; the ground between damaged areas was clear of debris (and no sign of anything penetrating the ground); and, especially towards the coast, the damage was scattered but clustered throughout a broad zone lying across the path of the wind. His conclusion is that a "progressive, wet microburst-cluster" or something similar was the cause.

tn2016Nov17/II *Trefnanney, near Welshpool, Montgomeryshire (52° 44' N 3° 13' W to 52° 44' N 3° 10' W, SJ 174148 to SJ 207148)*

This and most of the following tornadoes were discovered by Matt Clark during long hours of fieldwork over the weeks following 17 November (hindered at times by short days and frost and fog). Nearly all the evidence came from damaged trees, the few buildings in this rural area showing little, if any, effects. Most of the tracks began very narrow and intense, then fanned out and merged with larger areas of apparently non-tornadic damage, such that the transition from one to the other was not clear (a pattern that has sometimes been observed during other site surveys). This differs from the normal tornado track, which is at its narrowest at both beginning and end, and widest in the middle. And it meant that whereas the start of each track could be pinpointed exactly the ends were more vague. He also found many other broad areas of tree damage from Montgomeryshire to Staffordshire that could not reasonably be attributed to tornadoes but sometimes contained pockets of intense damage. The retrospective nature of the investigation meant that it was not possible to obtain reported times for these tornadoes, so timings interpolated from radar (to within  $\pm 5$  minutes) have been used here.

This tornado just south of Trefnanney was surveyed on 23 December (after its earlier discovery on 26 November). Along a path of about 3 km from west to east at least 20 trees exhibited damage ranging from slight to severe, but the spread either side of the line precludes classifying this as a definite tornado. Force T1. Time about 1116 GMT. Like all the tornadoes investigated here this one appeared to be embedded in a broader and longer zone of lesser non-tornadic damage.

tn2016Nov17/III *Middletown, Montgomeryshire (52° 42' N 3° 03' W to 52° 42' N 3° 01' W, SJ 287116 to SJ 309122)*

This tornado was reported to us by Ms Clare Jowett, who experienced it at her home (SJ 305121) just outside Middletown (on the Wales/Shropshire border). At about 1110 GMT (while indoors) she became aware of 'a tremendous roaring sound', like a railway train or an aeroplane. On venturing out she saw rubbish boxes hurled into the air and swirled about the road and fallen leaves swirling in the air; a heavy garden table was raised and landed upside down, a tree came down in the garden, and her lane was blocked by other fallen trees. There was also damage in the village itself, where a caravan was overturned (SJ 300121) and its occupant (a teenage boy) slightly hurt, but friends 1½ km southwest of her house (at SJ 292112) did not have the same intensity of wind.

At Terence Meaden's suggestion she graciously agreed to look for other damage in the neighbourhood, and came back with a map of points that she discovered. These extended from east of Trewern to just beyond her own house, consisting mainly of tree damage but including minor damage to a railway bridge, making a track of 2.5 km from westsouthwest. Force T1/2. Later in the day she travelled southwest to Newtown (SO 1191) but the only other damage en route was an isolated fallen tree at SJ 266102 (not obviously part of the main track); and people in Newtown had noticed nothing unusual there.

Matt Clark inspected this area in the course of his other surveys and found a rather ill-defined path of weak damage from Trewern (SJ 285115) to beyond Wollaston (SJ 346123). Time about 1120 GMT.

tn2016Nov17/IV *Haughton, near Four Crosses, Montgomeryshire\* (52° 45' N 3° 02' W to 52° 45' N 3° 00' W, SJ 300182 to SJ 320179)*

This short narrow track up to 150 m wide and 2 km long from just north of west

(found on 27 January) soon merges with a much larger area of damage to the south of it but is indicative of a tornado of force T1 (moderate to severe damage to trees). Time about 1124 GMT.

\* The last few hundred metres of this track lie over the county (and country) boundary in Shropshire.

TN2016Nov17/V Kinton, near Nesscliffe, Shropshire (52° 46' N 2° 59' W to 52° 46' N 2° 56' W, SJ 339199 to SJ 373198)

Severe damage to trees found here on 27 January indicated a fairly definite tornado track of 3.5 km west to east, starting from near Farm Hall west of the hamlet of Kinton and ending near Kinton itself, by which point it had widened to about 300 m. Force T2. Time about 1127 GMT.

A few kilometres further on there was another trail of damage at Little Ness, from SJ 404195 to SJ 440199, passing through Adcote Girls' School (SJ 418194), from where a teacher, Ms Katy Rink, was quoted in the *Shropshire Star* (17 November): "Break time had just started and we suddenly noticed the leaves were flying by our windows horizontally. It was a furious tornado ... our front door blew in and our huge pictures in the lobby all blew off the walls and shattered. We also lost one of our beautiful window panels in the Great Hall. It was the most intense weather event I have ever experienced". It was felt, however, that the damage to trees here was too widely dispersed to be treated as a continuation of the tornado.

TN2016Nov17/VI Harmer Hill, Shropshire (52° 48' N 2° 47' W to 52° 48' N 2° 45' W, SJ 471225 to SJ 490224)

In an earlier visit to the area on 26 November Matt Clark found a very narrow track of damage to trees at Harmer Hill, beginning just west of the village near Webscott Farm and forming a track of 2 km from west to east, width up to 100 m. Force T1. Time about 1134 GMT. This again was within a longer area of damage that broadened substantially to the east where it became too wide to be a tornado (and continued to Shawbury Airfield where the gust of 73 knots was recorded at 1139 GMT).

TN2016Nov17/VII Clive to Acton Reynald, near Shawbury, Shropshire (52° 49' N 2° 45' W to 52° 48' N 2° 41' W, SJ 497241 to SJ 535235)

Another track of tree damage was found near Clive (26 November), beginning at Broughton Farm, passing just south of the church, and continuing to the hamlet of Acton Reynald, width no more than 100-150 m at the start, then broadening, making a length of 4 km from just north of west. Force T1. Time about 1138 GMT.

TN2016Nov17/VIII Hodnet, Shropshire (52° 50' N 2° 37' W to 52° 51' N 2° 35' W, SJ 581269 to SJ 607274)

During his visit to Shropshire on 23 December Matt Clark found a good tornado track at Hodnet, from the Shooting Range west of the village to near Hodnetheath to the south; this was particularly obvious from tree damage through Hopton Farm (SJ 601271). The track was 2.5 km from just south of west, starting very narrow at 20 m and gradually widening. Force T1. Time about 1143 GMT.

TN2016Nov17/IX Stoke Heath, near Market Drayton, Shropshire (52° 52' N 2° 32' W to 52° 52' N 2° 29' W, SJ 646308 to SJ 672304)

Returning to this area on 30 December Matt Clark discovered three more well-defined tracks, all showing quite intense damage to trees. One began north of Stoke

Heath (on the edge of the old Ternhill Airfield) and continued from just north of west for 2.5 km. This one too began very narrow (a few tens of metres) then widened to 100 m before spreading out over a much broader and less well-defined (non-tornadic) area. Force T1. Time about 1146 GMT (gust 55 knots at Ternhill at that time).

TN2016Nov17/X Hookgate, near Loggerheads, Staffordshire (52° 55' N 2° 25' W to 52° 55' N 2° 22' W, SJ 719349 to SJ 758352)

This track (seen on 30 December) was mainly evident at Woodend Farm, Hookgate (SJ 747350 but not named on O.S. maps), but appears to have begun north of Blore and continued to a kilometre east of Hookgate, a distance of 4 km from west to east, and then exhibited the same broadening trend as the others. Force T1. Time about 1152 GMT.

tn2016Nov17/XI Chapel Chorlton, near Stoke-on-Trent, Staffordshire (52° 56' N 2° 18' W to 52° 56' N 2° 16' W, SJ 804376 to SJ 822372)

The final track in this area was just south of Chapel Chorlton, where (as at Stoke Heath) there was severe damage over a narrow width, length about 2 km from just north of west. Force T1. Time about 1156 GMT.

q/tn2016Nov17 Meir, Stoke-on-Trent, Staffordshire (52° 59' N 2° 06' W, SJ 9342)

Mr Jason Rhodes reported a 'tornado' at about 1330 GMT that damaged a garden fence and shed, removed tiles from a roof, and blew down a tree, but gave no evidence that this was more than a squall.

tn2016Nov17/XII Meden Vale, Nottinghamshire (53° 13' N 1° 08' W to 53° 13' N 1° 06' W, SK 575693 to SK 604700)

The *Chad* of 17 November reported that a 'tornado left a trail of destruction' as it passed through Caunton Close (SK 577694) in Meden Vale in the early afternoon. A resident, Ms Georgina Carter, said: "... As many as 12 houses were damaged around us. Roof tiles are gone, chimneys hanging off. It was very scary ... It just happened in a second, things went whirling around, things were flying. One house was startled as a trampoline flew from one of their neighbours' gardens, straight across their own and into another, crashing into a shed". A neighbour, Ms Jill Hunt, added: "It was blowing and the tiles were flying around like sheets of paper. It was terrifying ...".

Tim Prosser of TORRO visited the scene the next day and confirmed that there was a defined path about 100 m wide starting at Egmanon Road in the village and continuing in a nearby wood (Holborn Hill Plantation on the O.S. map), making a length of 3 km from west to east. He spoke to a number of witnesses who gave a duration of between one and ten minutes for the intense wind and described damage similar to that mentioned above. Force probably T2.

q/tn2016Dec23 Rhosgadfan, near Caernarvon, Caernarvonshire (53° 05' N 4° 14' W, SH 507572)

The *Daily Post* (23 December) reported that 'hurricane force' winds had taken the roof off the village school at Rhosgadfan at about 1400 GMT; and there were indications that a tornado might have been responsible, but strong winds were occurring generally at that time. At 1200 GMT an intense depression, 950 mb, was centred south of Iceland and its active cold front was crossing Ireland and Scotland (and would have been in Snowdonia shortly after 1400 GMT).

PROVISIONAL TOTALS FOR THE YEAR (excluding Irish Republic)

2016	J	F	M	A	M	J	J	A	S	O	N	D	Total
TN	1	2	0	1	1	5	1	0	0	1	12	0	24
WS	1	0	0	2	0	1	2	0	0	2	0	0	8
FC	1	0	2	11	13	44	10	7	2	7	0	0	97
Number of days with:													
TN or WS	2	1	0	2	1	5	3	0	0	2	1	0	17
FC only	1	0	2	8	4	10	4	3	2	3	0	0	37
TN, WS, or FC	3	1	2	10	5	15	7	3	2	5	1	0	54

Whirlwinds in the Irish Republic

tn?2016Sep03 *Mountbellew, County Galway (53° 28' N 8° 30' W, M 6646)*

A report was received from Ms Christine Raftery of a 'tornado' that damaged a garden shed, fences, trees, and a telegraph pole at Ballinahattina in Mountbellew; the time was 1645 GMT and it lasted only 'seconds'. Although the weather pattern would not rule out a tornado we should require more evidence to accept the report as given.

At 1200 GMT a small depression, 1000 mb, was moving into northwest Ireland from the west; its occluding front, accompanied by a band of rather heavy showers and thunderstorms, would have been near Mountbellew about the time of the report (other fronts ahead of this system were crossing England and Wales).

Amendment to report for January-May 2008 (published in IJMet. vol. 34 pp. 23-29)

FC2008May31/I *Near Lapford, Devon (c 50° 53' N 3° 47' W, SS 7511)*

The *COL Bulletin* for May 2008 published a photograph of this funnel cloud seen about two miles (3 km) north-northeast of Lapford. Time of observation 1310 BST (1210 GMT). Information from Jonathan Webb of TORRO.

The observer of the above report, Mr Andrew Epstein, has provided the following additional details:

"Funnel cloud observed from West Farm, Lapford, in a NNE direction at a distance of approximately 1 mile, first spotted at 13.10 [BST], dissipated 13.30 [BST]. At ground level there was a very light NW breeze, it was warm and humid. The funnel cloud was observed through binoculars. There appeared to be a central core of spinning air moving upwards into a developing cumulus, and around this core the movement appeared towards the ground ... There was a brief light shower shortly after this event as the cumulus drifted overhead (moving in a SW direction), by which time the funnel cloud had disappeared."

ACKNOWLEDGEMENTS

We thank especially Matt Clark, John Mason, and Tim Prosser of TORRO for their thorough site investigations of the events of 17 November; we also thank Ms Clare Jowett and Mr Jason Rhodes for informing us about Middletown and Meir respectively for this date, and Peter Kirk and Simon Culling for information about some of the other events in this report.

